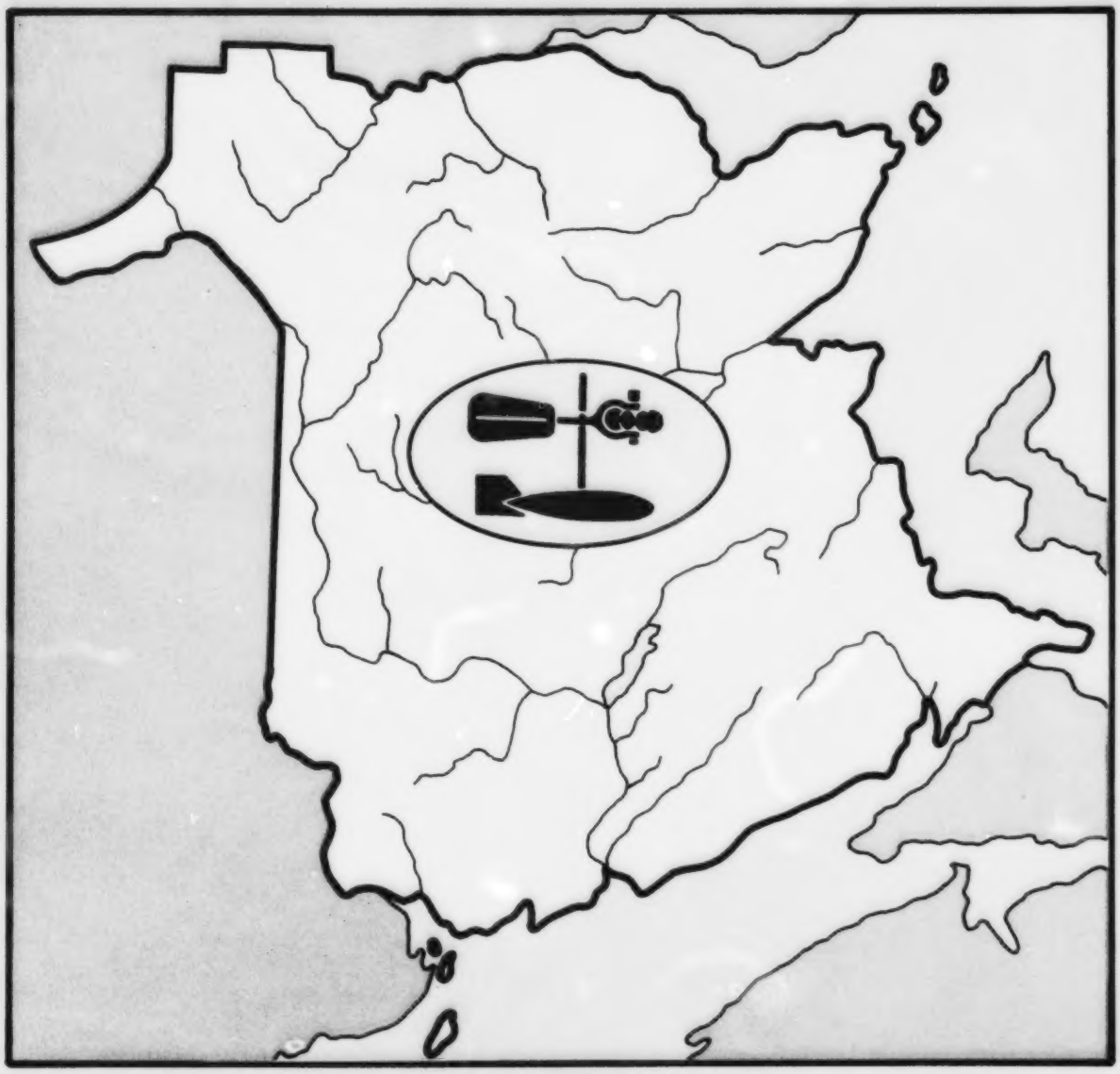
New Brunswick Hydrometric Network Evaluation

LEGISLATIVE LIBRARY
BIBLIOTHÈQUE DE L'ASSEMBLÉE LÉGISLATIVE
APR 17 1989
FREDERICTON, N.B.

Background Report No. 2
Delineation of Physiographic-Climatic Zones



April 1988

Environment Canada / Environnement Canada

New Brunswick Department of Municipal Affairs and Environment / Ministère des Affaires Municipales et de L'Environnement du Nouveau-Brunswick

NEW BRUNSWICK HYDROMETRIC NETWORK EVALUATION

BACKGROUND REPORT NO. 2

DELINEATION OF PHYSIOGRAPHIC-CLIMATIC ZONES

Environment Canada
Inland Waters/Lands
Dartmouth, Nova Scotia

New Brunswick Department of
Municipal Affairs and
Environment
Fredericton, New Brunswick

ABSTRACT

As part of the overall Hydrometric Network Evaluation of the Province of New Brunswick, a natural flow monitoring network was designed based on the physiographic and climatic regions of the province. Zones of general similarity were delineated then land use data were used to refine the divisions. The World Meteorological Organization station density guidelines were used to compare the size of a proposed minimum network to that of the present network. A minimum network scenario was then proposed based on a representative distribution of streams taking into consideration the range of drainage areas for natural flow streams found in each zone.

RESUME

Une des parties de l'évaluation du réseau hydrométrique de la province du Nouveau-Brunswick fut la conception d'un réseau de débit naturel basé sur les régions physiographiques et climatiques de la province. A partir de ces données, des zones de similarité furent établies et des données sur l'utilisation des terres ont par la suite raffinées ces divisions. Les lignes directrices de l'Organisation Mondiale Météorologique furent alors utilisées pour comparer le présent réseau à un réseau minimum sous leurs critères. Un scénerio pour un réseau minimum fut alors proposé basé sur une distribution représentative des cours d'eau prenant en considération l'étendue des aires des cours d'eau naturels de chaque zone.

TABLE OF CONTENTS

		Page
Abstract/Résumé		ii
Table of Contents		iii
List of Tables		v
List of Figures		vi
1.0	CHAPTER ONE: INTRODUCTION	1
2.0	CHAPTER TWO: HOMOGENEOUS HYDROLOGIC ZONE CONCEPT	3
3.0	CHAPTER THREE: CLIMATIC REGIONS OF NEW BRUNSWICK	5
	3.1 Region I - Bay of Fundy	5
	3.2 Region II - Eastern New Brunswick	7
	3.3 Region III - New Brunswick Lowlands	7
	3.4 Region IV - New Brunswick Highlands	7
	3.5 Summary	8
4.0	CHAPTER FOUR: PHYSIOGRAPHIC DIVISIONS	9
	4.1 Edmundston Highlands	12
	4.2 Chaleur Uplands	12
	4.3 New Brunswick Highlands	13
	4.3.1 Miramichi Highlands	13
	4.3.2 St. Croix Highlands	14
	4.3.3 Caledonian Highlands	14
	4.4 New Brunswick Lowlands	15
	4.5 Summary	16
5.0	CHAPTER FIVE: LAND USE DIVISIONS	17
6.0	CHAPTER SIX: DELINEATION OF PHYSIOGRAPHIC-CLIMATIC ZONES	19
7.0	CHAPTER SEVEN: NATURAL FLOW NETWORK	24
	7.1 Network Design Criteria	25
	7.2 Natural Flow Network Selection	28
8.0	CHAPTER EIGHT: CONCLUSIONS AND PROPOSED MINIMUM NETWORK	32

TABLE OF CONTENTS CONTINUED:

	Page
9.0 CHAPTER NINE: RECOMMENDATIONS	35
References	36
List of Contributors	37

LIST OF TABLES

		Page
Table 3.1	Regional Climatic Parameters of New Brunswick	8
Table 4.1	General Features of the Physiographic Divisions of New Brunswick	11
Table 5.1	Significant Land Use Categories by WSC Watershed Division	18
Table 6.1	Active Natural Flow Hydrometric Stations by Physiographic-Climatic Zone	22
Table 7.1	Minimum Density of Hydrologic Networks	26
Table 7.2	Minimum Network by Zone Using WMO Criteria	27
Table 7.3	Major Rivers of New Brunswick	29
Table 8.1	Minimum Regional Hydrology Network Scenario	33

LIST OF FIGURES

		Page
Figure 3.1	Climatic Regions of New Brunswick	6
Figure 4.1	Physiographic Subdivisions of New Brunswick	10
Figure 6.1	Physiographic-Climatic Zones of New Brunswick	20

1.0 INTRODUCTION

The New Brunswick Hydrometric Network Evaluation was a two-year study of the surface water quantity monitoring network in the province. The purpose of the study was to evaluate the entire network on its effectiveness to monitor the water resources. A series of four background reports examining various aspects of the study were produced. This report is the second of the series and deals mainly with the physiographic and climatic influences on the natural hydrology. It also proposes a design scenario of a minimum network to produce a representative sampling of the hydrology of the region.

Most hydrometric networks in the Atlantic Provinces date back to the early 1900's. They evolved from the need for information about streams which had potential for the development of hydroelectric power generation. The resulting stations in the network were limited in their purpose and were not planned with the idea of gaining information on the hydrology of the region other than possibly in a gross sense. Through the years, new needs for hydrometric data were added, which included knowledge of the hydrologic/hydraulic regimes of numerous streams. While many of these needs were site specific, an increasing number of needs required a general understanding of the regional hydrology.

Numerous studies have shown that by monitoring a representative sample of watersheds in a hydrologically homogeneous region that a good knowledge base of the characteristics of the water resource can be determined. Ideally the flows from the measured sites can be transferred to the ungauged sites through simple correlation methods such as proration, streamflow routing and more complex mathematical methods such as regression analysis and modelling. The problem, however is to define the homogeneous regions and select a good sample of the types of watersheds in the region. By taking into consideration the variations in climate and physiography, it is possible to develop a network which will aid in the transfer of information from one stream to another using simple mathematical models. Such a network can be receptive to answering many long-term needs for the management of the water resources. The underlying requirement for this regionalized approach to network planning and design is that the network be comprised of representative samples of streams over the network area. The number and distribution of these stations depends on the variety and range of physical conditions encountered.

One way to achieve a representative sampling of the stream network is to determine the characteristics of the stream-flows of all streams and group them together into zones of

homogeneous streamflow characteristics. To develop such a database would involve extensive measuring of a large number of streams over a long term. A more reasonable approach and one which could be accommodated within the economic and information constraints of today's world, would be to make inferences from the available knowledge of the area. To achieve this, the province is divided into areas which are similar in climate and physiography with the assumption that they will prove to be hydrologically homogeneous. This can be used as a starting point in developing a representative hydrometric network. The purpose of this report is to develop such a network.

2.0 HOMOGENEOUS HYDROLOGIC ZONE CONCEPT

Any land mass can be divided into sections and analysed using a number of specific parameters. To illustrate this point, the Province of New Brunswick could be divided into areas where the majority of the population have common cultural backgrounds, income levels and education. By overlaying maps of each of these delineations, areas of similarity would appear. In turn, it might be determined that certain areas correlate well with the sales of a specific commodity. Based on this knowledge, a decision could be made on opening a number of outlets for this commodity. Similarly for hydrologic purposes, we can divide a map of the province into areas based on a number of parameters which we know correlate well with hydrology. It can be postulated that areas with similar characteristics will behave hydrologically in a similar manner. Although there will be anomalies due to the assumptions made when dealing with large areas, this is not unexpected when using generalizations.

Hydrology can be simply described using the concept of the hydrologic cycle. This can be further simplified by dividing it into two major components: the climate, above the ground and the geology and soil, below the ground surface, which is influenced by the physiography. The interface between these components are where surface water is stored. The shape or slope of the surface influences the length of time water is stored on it and ultimately how it runs off or interacts with the above and below ground influences, such as evaporation and percolation.

By analysing the above and below ground features of the region, it is possible to make a general statement about the characteristics of the surface water runoff. A classification system can be developed based on the variation in the ranges of these features over the area. This can then be used to delineate areas of homogeneity or similarity to help in the design of a representative streamflow network.

The concept of homogeneity must, however, include the ability to detect differences in the hydrologic regime. The differences are influenced by the various physical factors involved in the hydrologic cycle. A homogeneous zone for this purpose can be defined as any area whose specific property be it climate, geology, land use, etc. is sufficiently similar or similarly varied over its entirety but at the same time significantly different from other adjacent areas, that the data can be treated as if from the same population.

In measuring surface water runoff, i.e. discharge, we are in essence measuring the residual or end product of the effects

of all the properties that make-up the watershed and the climatic factors acting upon it. The delineation of these areas are not necessarily at abrupt changes located at their boundaries, although in some cases, such as at geologic boundaries, this may be true. In general, it would be better to consider these boundaries as the midpoints of a gradual areal transition.

In the following sections, climate, physiography and land use data are discussed. These data are classified in ranges of characteristics and brought together to form zones. Each zone is expected to be different from the surrounding areas but, within it, the streamflow characteristics should on average be similar enough to be analysed as a homogeneous unit. By using this approach, it is possible to locate areas which are either inadequately or over-represented by the present network.

The delineation of these zones is but one simplified interpretation of a series of complex natural systems, which affect regional hydrology. There is no pretense that this is the only interpretation but it is one method of generalizing the influencing factors to achieve a practical solution. A more detailed analysis is possible but a great deal more information must be brought together. However, it is unlikly that a study in greater detail will be workable with this process. To do so would require that the scale of the analysis be brought down to the watershed level. Here such phenomena as the groundwater zones of recharge, transition and discharge and the effect of orographic lift on precipitation patterns can be considered. Realistically, a study of this detail is not warrented here.

3.0 CLIMATIC REGIONS OF NEW BRUNSWICK

The main driving force of regional hydrology is the regional climate. Precipitation, a major component of the climate is singularly the most important factor affecting runoff. Runoff varies directly with precipitation, however other factors such as the storage and melting of snow are also seasonally important factors. For the purpose of developing zones, the Atmospheric Environment Service of Environment Canada provided the map shown in Figure 3.1. Four, more or less, homogeneous climatic regions for New Brunswick are delineated. The main parameters used in the classification of the regions are annual precipitation, annual snowfall and the water equivalent of the snowpack on March 31st of each year. In the absence of quantitative data, topography was used to delineate boundaries between regions.

Again, it must be pointed out that boundaries should not be considered absolute since there are usually gradual changes in climate except where the boundaries and significant changes in topography coincide. In some cases, the climatic normals do not fit the classification. An example is Nepisiguit Falls, a station for which precipitation is measured at the bottom of a gorge; a location which certainly is not representative of the region.

Nearly all climate stations and therefore all regions exhibit a spring minimum and a fall maximum of precipitation. The significance of this can be demonstrated in the fact that, while much of the flooding in New Brunswick is associated with the spring runoff which is for the most part a snowmelt event, the design storm for the Mactaquac Dam is based on a fall rainstorm. These fall events are typically the results of low pressure sytems (sometimes hurricanes) which track up the eastern seaboard of the United States and often come inland along the Bay of Fundy Coast.

3.1 REGION I - BAY OF FUNDY

This region has a total annual precipitation ranging from 1200 to at least 1450 mm and an annual snowfall of 175 to 300 cm. The highest snowfall is in the higher terrain in the vicinity of Fundy National Park. The average water equivalent of the snowpack on March 31st ranges from 60 to 140 mm. There are a number of reasons for the existence of this distinct climatic region. The high total annual precipitation is due in part to its proximity to the major storm tracks on the east coast of North America and partly

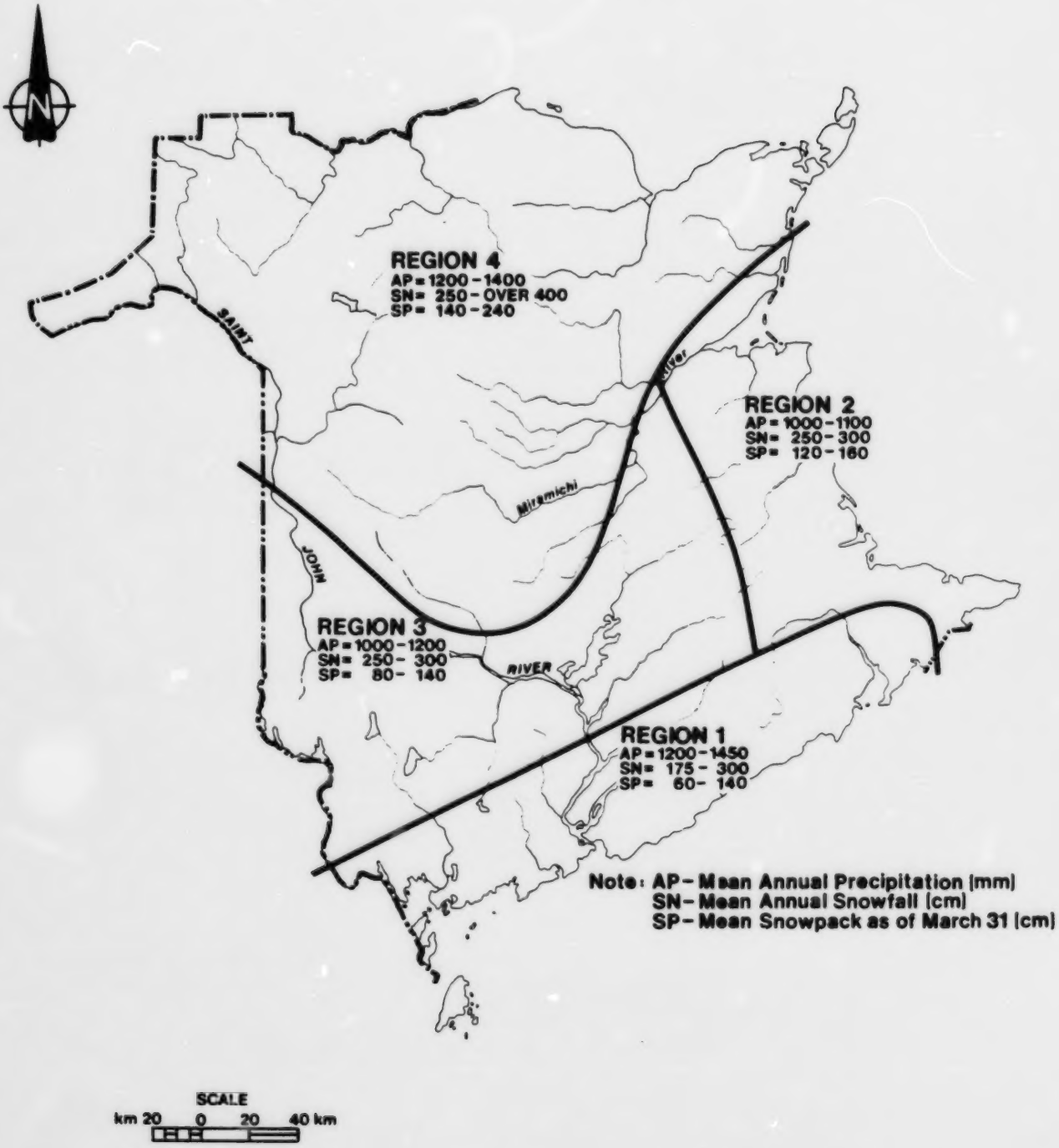

N
REGION 4
AP = 1200 - 1400
SN = 250 - OVER 400
SP = 140 - 240
SAINT
JOHN
RIVER
Miramichi
REGION 2
AP = 1000 - 1100
SN = 250 - 300
SP = 120 - 160
REGION 3
AP = 1000 - 1200
SN = 250 - 300
SP = 80 - 140
REGION 1
AP = 1200 - 1450
SN = 175 - 300
SP = 60 - 140
Note: AP - Mean Annual Precipitation (mm)
SN - Mean Annual Snowfall (cm)
SP - Mean Snowpack as of March 31 (cm)
SCALE
km 20 0 20 40 km

Figure 3.1 Climatic Regions of New Brunswick

as a result of the influence of the Bay of Fundy. The increase in friction as airmasses ahead of storms move from open water to land coupled with orographic lift result in a precipitation maximum along this coast. The high tides in the Bay of Fundy prevent the formation of an ice cover in winter and the resultant open water has a moderating influence on the coastal area. The proximity to the major storm tracks also results in the most frequent penetration of above freezing airmasses for the Province of New Brunswick. The snowcover is therefore the least persistent.

3.2 REGION II - EASTERN NEW BRUNSWICK

The total annual precipitation ranges from 1000 to 1100 mm and the annual snowfall from 250 to 350 cm. The amount of snowfall is in part dependant on the ice cover over the Gulf of St. Lawrence. In years when the ice cover is established late or does not persist, snowfall tends to be higher. Moisture picked up by airmasses that move in from open water in the Gulf is precipitated out because of the coastal convergence phenomenon and orographic lift. The water equivalent of the snowpack on March 31st ranges from 120 to 160 mm. Snow cover tends to be more reliable than for the Fundy Region because of a lower incidence of above freezing airmasses which result in winter thaws. In terms of total annual precipitation, this region is the most homogeneous of all the regions.

3.3 REGION III - NEW BRUNSWICK LOWLANDS

This region is made up mainly of the lower portion of the Saint John River Valley and portions of the Miramichi Valley, with the exception of the coastal areas of the previous two regions. Total annual precipitation ranges from 1000 to 1200 mm and annual snowfall from 250 to 300 cm. The frequency of penetration of above freezing airmasses and therefore winter thaws is similar to the Eastern New Brunswick Region; that is, lower than for the Bay of Fundy Region. The water equivalent of the snowpack on March 31st ranges from 80 mm in the south to 140 mm in the north of this region.

3.4 REGION IV - NEW BRUNSWICK HIGHLANDS

Except for the fringes of this region, total annual precipitation in this region ranges from 1200 to 1400 mm or more. Annual snowfall ranges from 250 to in excess of 400 cm. The upper limits are in doubt because of the lack of climate stations in the higher terrain. This region is least affected by winter thaws, reflecting the rather

infrequent penetration of above freezing airmasses that far north and the elevation of the terrain. Water equivalent of the snowpack on March 31st ranges from 140 to 240 mm, the highest of the four regions.

3.5 SUMMARY

Table 3.1 shows the ranges of the climatic parameters used to delineate the climatic zones. One first notices the small difference in the ranges of precipitation between the zones. However, the main difference appears to be the amount of snow which falls and its persistence on the ground during the winter season. This no doubt has its greatest effect on the flood and mean flows; however, it may also be an indication of winter low flows. The major differences in flow will no doubt be seen when this is combined with other physiographic and land use phenomena.

Table 3.1

Regional Climatic Parameters of New Brunswick

	CLIMATIC REGION	PRECIPITATION (mm)	SNOWFALL (cm)	SNOWPACK (cm)
I	Bay of Fundy	1200->1450	175-300	60-140
II	Eastern N.B.	1000-1100	250-300	120-160
III	N.B. Lowlands	1000-1200	250-300	80-140
IV	N.B. Highlands	1200-1400	250->400	140-240

4.0 PHYSIOGRAPHIC DIVISIONS

Topography, which is a function of the underlying bedrock geology and the overlying surficial deposits, is the most important mechanism acting on any precipitation found in excess to the infiltration capacity of the soil. This surface ultimately affects the characteristics of the runoff. In general, the greater the slope, the quicker the runoff; however, these and other factors such as the pattern and the efficiency of the drainage system all influence the runoff character. These parameters can be grouped and delineated using the physiographic descriptions of the province.

The physiographic divisions of New Brunswick as defined by Bostock (1970) and used in previous analyses of the network were revised by Rampton et al. (1984) and are shown in Figure 4.1. This revised map more closely reflects the tectonostratigraphic divisions. These divisions are the main building blocks of the zonal framework from which the network will evolve. The principal physiographic divisions as shown in the figure are:

1. The Edmundston Highlands
2. The Chaleur Uplands
3. The New Brunswick Highlands
4. The New Brunswick Lowlands.

These divisions have been created largely by the physical processes which have acted upon them; namely, submersion and sedimentation, glaciation and uplifting, folding, intrusion and erosion. These principal areas have been further divided into a total of 39 distinct subdivisions. However, due to the low density of the stream gauge network and lack of coincidence of the drainage boundaries with these subdivisions, it was not feasible at the network scale to partition the hydrologic network strictly along these lines. The distinct differences between these subdivisions will no doubt account for much of the variation in streamflows within a principal division. It is possible in spite of this to use the information from these areas to formulate a mosaic of more or less uniquely different zones. This is not to suggest that the divisions are themselves homogeneous, but that the overall characteristics portray sufficient similarities to allow these to be merged or lumped together for this analysis. The following is a brief overview of each of these physiographic divisions, with reference to the generalities and distinctive features of each. Table 4.1 summarizes some of the main features of the areas.

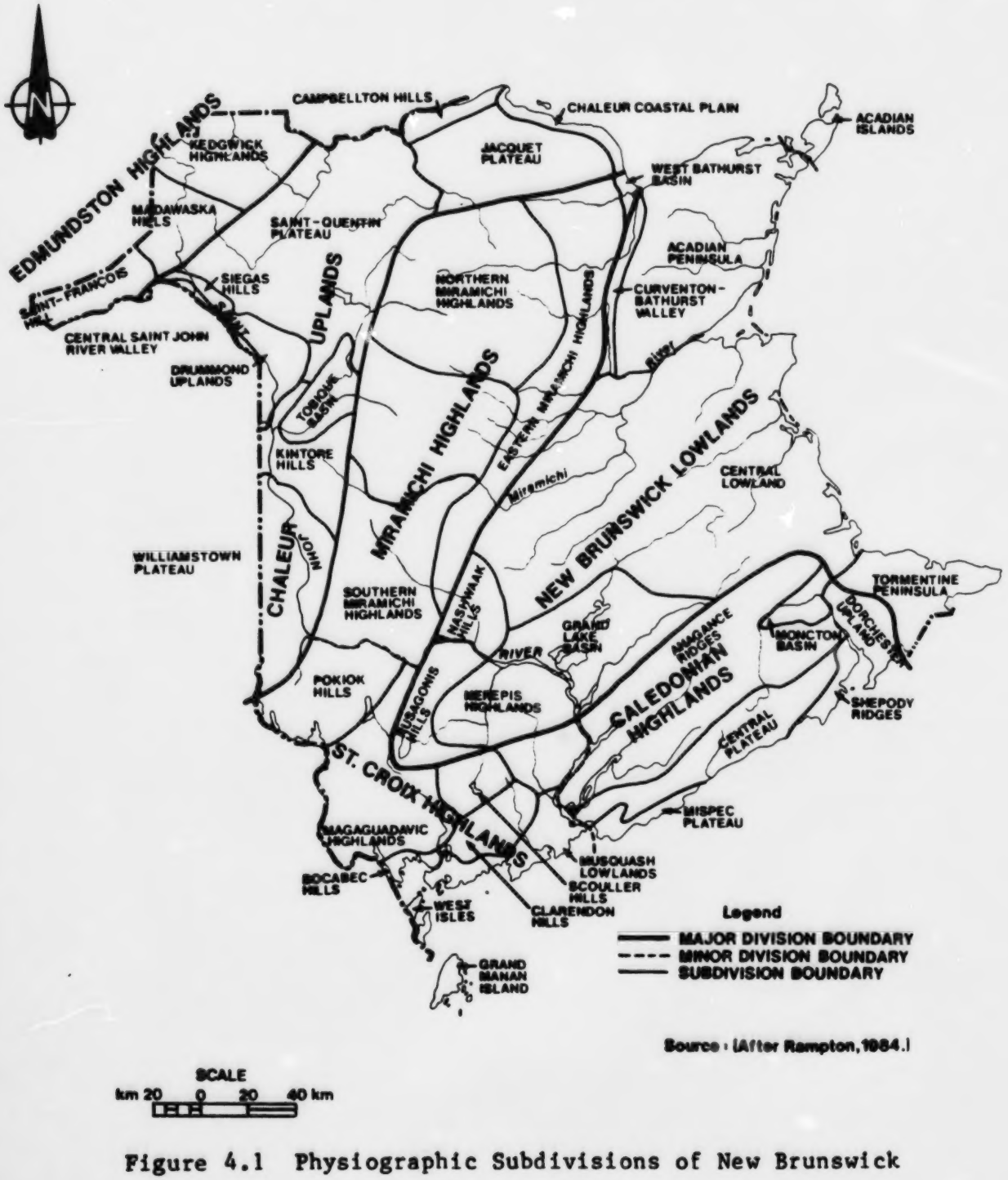


Figure 4.1 Physiographic Subdivisions of New Brunswick

Table 4.1

GENERAL FEATURES OF THE PHYSIOGRAPHIC DIVISIONS OF NEW BRUNSWICK

PARAMETER	EDMUNDSTON HIGHLANDS	CHALEUR UPLANDS	NEW BRUNSWICK HIGHLANDS			NEW BRUNSWICK LOWLANDS
			MIRAMICHI	ST. CROIX	CALEDONIAN	
TERRAIN surface	hilly and rugged	slightly undulating tilted plateau interrupted by clusters of hills	rugged and hilly peaks form ridges broad depressions	varying hilly to flat	gently rolling plateau and ridge valley structures	flat to gently sloping plain
ELEVATION range	360 to 580 m	150 to 450 m	300 m in south to 600 m in north	200 to 400 m (hills) up to 90 m (lowlands)	215 to 305 m	40 m to 185 m
PEAKS	604 m	580 m	820 m	220 to 400 m (hills) 90 to 150 (lowlands)	360 to 400 m	210 m at western boundary
RELIEF stream	210 to 245 m(minor) 300 to 365 m(major)	30 to 60 m flat areas 120 to 245 m in hills	210 to 250 m	70 to 220 m (hills) 30 to 75 m (lowlands)	60 to 90 m plateau up to 270 on coast	15 to 60 m with some 100 m scarps
DRAINAGE soil	well	well except for poor in valleys bottoms	well, except for poor in valley bottoms	well in the hills to poor in the flat areas	generally good, but poor in broad valleys	moderate to fair but poor in flat areas
DRAINAGE pattern	parallel to complex	generally dendritic but parallel in the north	generally dendritic	varied by glaciation	trellis	irregular

4.1 EDMUNDSTON HIGHLANDS

This area runs along the Gaspé Peninsula skirting the northern tip of the State of Maine and the northeast corner of the Province of New Brunswick. It is bounded by the Chaleur Uplands to the southeast and separated from it by a discontinuous, 60 to 90 m high escarpment. The highlands within the province are subdivided into the Saint François Hills, Madawaska Hills and the Kedgwick Highlands. The terrain is hilly and rugged with summits rising in elevation from 360 m near the Madawaska River to over 580 m near the northern edge. Relief within the hills is commonly between 120 and 215 m with higher values between 210 and 245 m along most minor streams and between 300 and 365 m along deeply entrenched rivers such as the Patapedia and the Kedgwick. The hills and ridges are moderately steep-sided with broad crests. The area is typically well drained except for some parts of wider valleys such as the Madawaska River Valley and a few broad depressions which are poorly drained where they form headwaters. The surficial geology is comprised mainly of thin morainal sediments which include loamy till, silt, sand and gravel.

In the areas of higher elevation, forest cover is of the Gaspé Section of the Boreal Forest Region. The major forest cover types are dominated by conifers, though mixed conifer-hardwood stands are not uncommon. The remaining forest cover is comprised of the Temiscouata-Restigouche Section of the Great Lakes-St. Lawrence Forest Region in the intermediate elevations. The cover types here range from deciduous species on the hill tops to coniferous species in the valleys.

4.2 CHALEUR UPLANDS

This division consists primarily of an elevated slightly undulating and tilted plateau locally dissected near major streams and interrupted by clusters of hills. The uplands include most of the Saint John River Valley upstream of the Town of Woodstock and much of the Restigouche River and Upsalquitch River Basins. Elevations generally range from 150 to 450 m above sea level however, a few peaks approach 580 m. While the area has been divided into 10 subdivisions, the core of the uplands consists of the Saint-Quentin and Jacquet Plateaus in the northern half. For the most part, these plateaus have an undulating surface. There are, however, broad depressions centred near the Saint-Quentin and Sisson Branch Reservoirs as well as a broad trough running parallel to portions of the Grand and Restigouche Rivers. The relief is 30 to 60 m in the gently rolling

plateaus and uplands where elevations range from 270 to 370 m for Saint-Quentin and up to 360 to 400 m for Jacquet. The plateaus are moderately well drained except for a few poorly drained low flat areas.

The Williamstown Plateau, Drummond Uplands and Tobique Basin are similar in relief to the Saint-Quentin Plateau but the elevations are much lower. The eastern part of the uplands is highly influenced by the Saint John River Valley whose tributaries are deeply incised into the surrounding land. The relief in the Kintore Hills is much greater, ranging from 120 to 245 m. The elevations blend unnoticeably into the neighbouring highlands. The area is well drained due to the relief.

The forest cover in the northern and eastern portion of the division is mixed with the deciduous species on the hilltops and the coniferous in the valleys. The eastern portion is predominantly hardwood in character but the fertile soils and favourable topography have led to extensive clearing for agricultural purposes.

4.3 NEW BRUNSWICK HIGHLANDS

The highlands have been divided into three major subdivisions whose characteristics are distinct enough to justify separating and discussing individually.

4.3.1 Miramichi Highlands

This area is characterized by hilly to mountainous terrain with peak elevations ranging from just over 300 m in the south to 680 m in the north, with Mount Carleton the highest peak in the area with an elevation of 820 m. While the topography is rugged and hilly, the core of the north and central subdivisions is comprised of numerous peaks some of which join to form continuous ridges. The relief in this area is more commonly in the 210 to 250 m range, although Mount Carleton at an elevation of 820 m has a relief of 490 m above the surrounding area.

Throughout the area the soil is generally well drained due to the relief although some valley bottoms display poor drainage. The drainage patterns are mostly dendritic, but some parallel patterns are noted in the Eastern Miramichi Highlands, which form a transition between the hill and mountain core and the plain to the east.

Generally, the high relief streams are narrow and deeply incised, but the valleys broaden out as the slope decreases and lakes are noted along with poorly drained ground.

Forest cover of the higher areas is predominantly coniferous; however, some tolerant hardwood stands do exist. The forest transforms into a mixed and then hardwood forest as the elevations decrease especially as you move south in the area.

4.3.2 St. Croix Highlands

The St. Croix Highlands stand in the southwest corner of the province and are only considered highlands because they are elevated above the Bay of Fundy to the south and the New Brunswick Lowlands to the northeast. Much of the highlands are composed of hilly areas separated by scarps or major river valleys with maximum elevations generally ranging from 220 to 445 m and relief in the 70 to 220 m range. Because of past glacial action in this area, the drainage varies from poor to well drained and the patterns are quite varied. The exceptions to the otherwise rugged terrain are the Magaguadavic Highlands, a relatively flat undulating plain which generally lies below 210 m elevation with varied but generally low relief and the Musquash Lowlands, an undulating plain with maximum elevations near 90 m and relief as high as 60 m.

The forest in this area is predominantly hardwood although some conifers do hold ground in the valleys and on lower flats.

4.3.3 Caledonian Highlands

The Caledonian Highlands have complex geomorphology and geology. This includes a central plateau underlain primarily by Precambrian rocks and boundary areas underlain primarily by folded and faulted Carboniferous rocks. The Central Plateau is gently rolling in nature with maximum elevations of 360 to 400 m. Streams here are not as incised as experienced elsewhere in the area but become increasingly so as the streams come to the edge of the plateau; consequently, the relief is generally only 60 to 90 m. The Mispec Plateau is similar to the Central Plateau but at a lower elevation of 75 to 150 m.

The other major area in this division is the Anagance Ridges, which is a prime example of ridge and valley topography paralleling the structural trends. Ridge top elevations range from 215 to 305 m. The stream pattern of the major streams displays a parallel trend as dictated by the structure. The drainage is generally good due to the higher relief; however, in broad valley bottoms clogged by glacial drift or filled with alluvium, the drainage is reduced to poor. The Moncton Basin is an extension and broadening of one of the valleys within the Anagance Ridges.

The Dorchester Upland consists of two ridges separated by the Memramcook River, the northern part being comprised of well drained ridges rising to an elevation of 120 to 165 m, whereas the southern part is relatively flat, poorly drained and 45 to 60 m in elevation.

The forest cover here ranges from the hardwoods in the higher altitudes to conifers on the lower elevations, especially where the lower slopes impede the drainage.

4.4 NEW BRUNSWICK LOWLANDS

The New Brunswick Lowlands are part of the Maritime Plain which encompasses much of the three Maritime Provinces. In general, the area is a flat to gently sloping plain dipping to the east. The only interruptions are the Curventon-Bathurst Valley in the north and the Grand Lake Basin in the southwest. The elevations of hills and ridges range from 40 m along the coast to 210 m in the Rusagonis Hills and along the transition slopes to the highlands. The relief typically ranges from 15 to 60 m but some scarps and incised channels in the Nashwaak Hills and Rusagonis Hills and the Curventon-Bathurst Valley reach 100 m.

With the exception of those few well drained higher sloped areas and the poorly drained flat areas, the drainage is for the most part moderate to fair.

The forest cover is predominantly coniferous in character although some hardwood stands do abound on well drained sites.

4.5 SUMMARY

The province has been divided into large areas of generally similar physiography and climate. There are, however, anomalies within these areas and subdivision to a greater degree is possible. Unfortunately, this would create a mosaic that would prove too cumbersome to use in an analysis of this type because most watersheds will portray more of their true uniqueness. The parameters that make these unique may be introduced as station attributes that can be used to help explain the variation between watersheds through the use of a data transfer model.

5.0 LAND USE DIVISIONS

The Canadian Land Use Management Program (CLUMP) database provides information on various classes of agricultural and forestry related land use. It also denotes wetland areas as well as built-up areas and various site-specific land uses. The database was delineated on subdivisions of the Water Survey of Canada (WSC) basin delineation nomenclature; i.e. 01AR denotes the St. Croix River and tributaries. These delineations facilitate the application of land use data to hydrologic considerations. While this database was developed in the early seventies, geographers working in this field felt that it was still representative outside the urbanizing areas. Since urban areas are a very small part of the network, it is anticipated that this would not diminish the value of the data to this project.

A summary of the data provided in Table 5.1 shows that approximately 85% of the province is covered by forest. Those areas which are used for agriculture tend to be centralized in certain basins, especially along the Saint John and Kennebecasis Rivers. Likewise, wetlands were concentrated in specific areas.

Land use data were analysed for trends which could be used to help in the delineation of the homogeneous zones. Areas which showed the proportion of marshland greater than 5% or agricultural lands greater than 10% of the drainage area were used to help delineate the zone boundaries. In many cases, these areas were already delineated along the climatic and/or physiographic divisions and these additional data helped support the delineation lines.

Table 5.1

Significant Land Use Categories by WSC Watershed Division

WSC DRAINAGE DIVISION	FOREST AREA km^2	FOREST AREA %	AGRICULTURAL AREA km^2	AGRICULTURAL AREA %	MARSHLAND AREA km^2	MARSHLAND AREA %
01AD	693	78.3	181	20.4	-	-
01AF	3010	85.4	479	13.9	-	-
01AG	67	64.4	37	35.3	-	-
01AH	4163	97.2	109	2.4	-	-
01AJ	1439	64.9	754	34.0	-	-
01AK	2863	81.0	543	15.3	103	2.9
01AL	1558	90.7	143	8.2	8	0.4
01AM	1418	72.0	139	7.0	67	3.4
01AN	1736	93.0	49	2.5	73	3.9
01AO	1762	80.1	138	6.2	104	4.7
01AP	4375	72.8	881	14.5	89	1.4
01AQ	2811	93.4	79	2.6	60	1.9
01AR	1964	87.0	195	8.6	74	3.2
01BA	1489	94.0	91	5.7	1	-
01BB	1263	99.8	-	-	-	-
01BC	980	95.9	40	3.8	-	-
01BE	2840	99.4	8	0.2	1	-
01BJ	2931	89.7	311	9.4	3	-
01BK	2281	98.7	12	0.4	11	0.4
01BL	2650	75.4	444	12.5	189	5.4
01BM	2762	98.0	38	1.3	13	0.4
01BN	1923	94.0	42	2.0	75	3.6
01BO	3645	90.6	217	5.3	137	3.4
01BP	1313	99.2	9	0.6	-	-
01BQ	2093	99.0	9	0.6	-	-
01BR	1595	76.0	181	8.5	307	14.6
01BS	1779	71.8	612	24.6	73	2.9
01BT	997	67.8	410	27.9	50	3.4
01BU	1965	76.7	160	20.3	36	1.4
01BV	1565	92.5	63	3.7	29	1.7
TOTAL	61930	84.3	6374	8.7	1492	2.0

NOTES: Percentages are based on the total land and water areas for each basin and the area of the Province of New Brunswick (73440 km^2)

Totals reflect only 95% of the area, the remaining 5% is composed of built-up areas and site specific land uses which are too dispersed to impact upon this analysis.

6.0 DELINEATION OF PHYSIOGRAPHIC - CLIMATIC ZONES

The delineation of zones based on physiographic and climatic data is an attempt to determine areas which should be hydrologically homogeneous. The concept of homogeneity in hydrology must be tempered with the reality that the closer a subject is studied, the less homogeneous it appears. One has only to look at different scale maps to notice that areas which appeared uniform on the small scale map suddenly have quite different features against one of a larger scale. The main difference lies in the degree of detail that is required to perform the task; the task being, to detect the variations in runoff between the watersheds through the hydrometric data collection program.

By overlaying the maps delineated using the major influencing parameters, it is possible to determine a new set of quasi-homogeneous zones. These zones are the intersections of the generalized physiographic, climatic and land use zones which are known to influence the streamflow regime. While there are many other influencing factors, it is not reasonable on a provincial scale to include specific quantitative parameters, such as area of lakes and swamps, area controlled by lakes and swamps, or effective channel slope. These characteristics are most likely unique to a part of a watershed rather than a region. The data may lead to a better definition but are not used herein as they can not be effectively used in this type of analysis. However, they can be used in regional analyses as demonstrated in the companion report, "Background Report NO. 3 - Regional Hydrology and Data Transfer Methodologies". Factors such as area of lake and swamp are typically used to explain much of the variance and consequently reduce the errors of a transfer function or model.

Within the province, 15 zones have been determined by overlaying the physiographic, climate and land use mosaics and dividing them along their intersections. The divisions are shown in Figure 6.1. Zone 16, although in the State of Maine, was included for completeness because of its impact on the upper Saint John River. Zones were typically delineated along the nearest basin or watershed divide, if it was noted that the intersections were close to the divide. This was justified on the basis that the division lines of the physiographic, climatic and land use information are generalized or smoothed lines and the use of entire drainage areas simplifies the selection of the zones for the purposes of this exercise.

The main exceptions to the basin/zone interface are the main stem of the Saint John River and those large streams which

Figure 6.1 Physiographic-Climatic Zones of New Brunswick

flow eastward from the Edmundston Highlands onto the Chaleur Uplands such as the Restigouche River or from the New Brunswick Highlands onto the Lowlands such as the Southwest Miramichi River. Here, dramatic physical changes are noted between the zones through which these rivers flow.

The existing natural flow stations found in each zone are listed in Table 6.1. The data from the hydrometric stations within each zone were first correlated with each other using annual and monthly mean discharges. Selected stations were then correlated with stations in adjacent zones to test the validity of the delineations. As a result of these analyses, minor adjustments were made to the zone boundaries where they could be justified by re-assessment of the physiographic data.

It must be realized that these zones represent idealized homogeneous areas and there will be streams within each zone that display characteristics other than what have been sampled. The characteristics of these streams may vary widely from the norm and will appear to be unique within the zone. This is most noticeable in small watersheds of say 50 km^2 or less where the mixture of physical characteristics may not be as wide as the average watershed in the zone, resulting in a different effect on the hydrologic regime. However, on the average, the individual areas within the zone share a number of characteristics which should correlate reasonably well with the hydrology of the zone. Any variation must be accepted as a fact of nature and minimized within our abilities to monitor a large enough sample to represent the true variance of the streams of the region.

Table 6.1

ACTIVE NATURAL FLOW HYDROMETRIC STATIONS BY PHYSIOGRAPHIC-CLIMATIC ZONES

ZONE	STATION NUMBER	DRAINAGE AREA (km^2)	MEAN ANNUAL FLOW (m^3/s)	PERIOD OF RECORD 60 65 70 75 80 86	STATION NAME
1	01AQ001	239	7.46	<----------	LEPREAU RIVER
	01AQ008	197	n/a	-----	PISKAHEGAN RIVER
	01AR006	115	2.93	----------	DENNIS STREAM
	01AR012	-	.229	----------	CHAMCOOK STREAM
2	01AM001	557	12.4	----------	NW OROMOCTO RIVER
	01AO009	93.2	2.58	----------	BURPEE MILLSTREAM
	01AP006	293	7.18	----------	NEREPIS RIVER
3	01AP004	1100	26.0	----------	KENNEBECASIS RIVER
	01BU002	391	8.31	----------	PETITCODIAC RIVER
	01BU003	129	3.74	----------	TURTLE CREEK
4	01BV006	130	5.45	----------	POINT WOLFE RIVER
5	01AJ003	1210	26.5	----------	MEDUXNEKEAG RIVER
	01AJ004	484	10.3	----------	BIG PRESQUE ISLE STREAM
	01AJ010	350	7.96	----------	BECAGUIMEC STREAM
	01AJ011	156	3.42	----------	COLD STREAM
	01AK001	234	5.06	<----------	SHOGOMOC STREAM
	01AK005	26.9	.560	----------	MID.BR. NASHWAAKSIS STR.(ROYAL)
	01AK006	5.70	.103	----------	MID.BR. NASHWAAKSIS STR.(FARM)
	01AK007	240	5.29	----------	NACKAWIC RIVER
	01AK008	531	11.3	----------	EEL RIVER
	01AL002	1450	36.2	----------	NASHWAAK R.(DURHAM)
	01AL003	6.48	.196	----------	HAYDEN BROOK
	01AL004	3.89	.114	----------	NARROWS MOUNTAIN BROOK
	01AL008	641	17.1	-----	NASHWAAK R.(STANLEY)
6	*01BO001	5050	118	< ----------	SW MIRAMICHI RIVER
7	01AN001	34.4	.965	----------	CASTAWAY BROOK
	01AN002	1050	24.6	----------	SALMON RIVER (CASTAWAY)
	01AP002	668	13.5	< ----------	CANAAN RIVER
8	01BO003	484	10.6	----------	BARNABY RIVER
	01BR001	177	3.97	< ----------	KOUCHIBOUGUAC RIVER
	01BS001	166	3.84	----------	COAL BRANCH RIVER
	01BT001	32.1	.576	--	KINNEAR RIVER

< - INDICATES DATA IS ALSO AVAILABLE PRIOR TO 1960
* - INDICATES THAT STATION MEASURES THE RUNOFF FROM MORE THAN ONE ZONE

continued...

Table 6.1 (concluded)

ACTIVE NATURAL FLOW HYDROMETRIC STATIONS BY PHYSIOGRAPHIC-CLIMATIC ZONE

ZONE	STATION NUMBER	DRAINAGE AREA (km^2)	MEAN ANNUAL FLOW (m^3/s)	PERIOD OF RECORD 60 65 70 75 80 86	STATION NAME
9	*01AE001	2260	49.9	<----------	FISH RIVER
	01AF007	339	7.71	----------	GRANDE RIVIERE
	01AG002	199	3.89	----------	LIMESTONE RIVER
10	01AH005	230	4.55	----------	MAMOZEKEL RIVER
	*01BC001	3160	67.6	----------	RESTIGOUCHE R. (KEDGWICK)
	01BE001	2270	41.7	<----------	UPSALQUITCH RIVER
	*01BJ007	7740	171	----------	RESTIGOUCHE R (RAFTING)
11	*01B0001	5050	118	< ----------	SW MIRAMICHI RIVER
	01B0002	611	15.2	----------	RENOUS RIVER
	01BP001	1340	33.3	<----------	LITTLE SW MIRAMICHI R.
12	01BK006	13.0	.331	------	FORTY MILE BROOK
	01BQ001	948	22.0	----------	NW MIRAMICHI RIVER
13	01BL001	173	3.31	----------	BASS RIVER
	01BL002	173	3.95	----------	RIVIERE CARAQUET
	01BL003	383	8.93	----------	BIG TRACADIE RIVER
	01B0004	316	8.87	---------	BARTIBOG RIVER
14	*01AD002	14700	277	<----------	SAINT JOHN R.(FT KENT)
	01AD003	1350	25.6	<----------	ST. FRANCIS RIVER
	*01BC001	3160	67.6	----------	RESTIGOUCHE R. (KEDGWICK)
	*01BJ007	7740	171	----------	RESTIGOUCHE R (RAFTING)
15	01BJ001	363	7.88	<----------	TETAGOUCHE RIVER
	01BJ003	510	10.9	----------	JACQUET RIVER
	01BJ010	190	4.19	------	MIDDLE RIVER
	01BJ011	123	2.85	------	NIGADOO RIVER
	01BJ012	43.2	1.07	----	EEL RIVER (DUNDEE)
16	*01AD002	14700	277	<----------	SAINT JOHN R.(FT KENT)
	*01AE001	2260	49.9	<----------	FISH RIVER

< - INDICATES DATA IS ALSO AVAILABLE PRIOR TO 1960
* - INDICATES THAT STATION MEASURES THE RUNOFF FROM MORE THAN ONE ZONE

7.0 NATURAL FLOW NETWORK

The central objective of the natural flow network is to provide as representative a sample of the streamflow of the region as possible. The database from such a network is essential for the responsible management of the resource. It should provide information on one major component of the hydrologic cycle, namely the natural runoff.

A thorough understanding of the natural ranges of runoff over the region is important to the economic development of the region. Runoff data are directly and indirectly used in such activities as; the effective design of stream crossings where transportation routes or pipelines intersect streams, the design and operation of water supplies and waste treatment facilities required for municipal and industrial development, the effective design and operation of hydropower generating facilities and the preservation and development of the agricultural, fisheries and wildlife resources. Without these data there will be more opportunities for mistakes to occur which will be costly to the economy and the environment of the region.

In discussing the concept of natural flow for hydrologic purposes, it is easier to explain what it is not, rather than what it is. Streams whose flows are regulated by dams or other man-made structures have a changed temporal streamflow distribution because the natural routing of the runoff is affected. The degree of regulation can vary with any immediate operational need for change, as dictated by an operating system or rule curve, rather than natural forces. These streams are generally considered to be an unknown and an unwanted quantity in a regional hydrologic analysis.

The question which must be asked is whether the regulation of the flow affects the shape of the hydrograph to the degree that differences in the hourly, daily, monthly or annual runoff are significant. The magnitude of the regulation is therefore of great importance in determining the utility of a station for regional hydrology. Unfortunately, this task would be a study in itself and can not be properly addressed here. Consequently, the establishment of stations on regulated streams will not be considered as part of the regional hydrology network. It then remains to develop a network from those streams which are unregulated. To do this requires some guidelines or criteria.

7.1 NETWORK DESIGN CRITERIA

Once the homogeneous hydrologic zones have been delineated, it is important to determine the number of stations required to establish a representative network. Ideally, each zone should contain a mix of stations which portray the characteristics of the zone. Within the economic constraints of any data collection program, it is often required that a minimum number of stations be selected which will give sufficient information for planning and design decisions. The minimum network should at least, for the effort expended minimize or ascertain the degree of risk in using data or information interpreted from the network stations. Just as a little bit of knowledge is a dangerous thing, a little bit of data can lead to a false conclusion if a significant sample has not been measured. There appear to be no rigorous rules pertaining to the number or distribution of the stations in a zone although there are some guidelines which have been considered for other networks.

One set of criteria is the World Meteorological Organization (1974) guidelines on minimum networks which are briefly outlined in Table 7.1. These guidelines are designed as a starting point for developing countries and are used only for comparative purposes. Under these criteria, much of New Brunswick would be classed as Type II regions(mountainous) but, since the "mountains" are small by world standards, the minimum density range of one station per 1000 km^2 would appear to be reasonable. Much of the New Brunswick Lowlands and some parts of the Uplands can be classed as Type I(flat) but here the plain is rather rough in nature and a density range in the order of one station per 1500 km^2 would be reasonable under this criteria.

Table 7.2 lists the approximate area of each physiographic-climatic zone and suggests a minimum number of stations using the WMO minimum network guidelines. Comparing the number of presently existing stations suitable for regional hydrology with those proposed by the above criteria, it can be seen that the present network is less than minimum under these guidelines but above minimum on a few zones. These guidelines could be met by simply redistributing some of these stations. There are still some problems with applying the WMO guidelines in that they do not appear to provide a large enough minimum sample of stations in some zones to fully represent the range in drainage areas. To remedy this problem, stations for each zone should be selected over the range of large, medium and small streams. This criteria will be called 'drainage range sampling' for the lack of a better term.

Table 7.1

Minimum Density of Hydrologic Networks

	TYPE OF REGION	RANGE OF NORMS FOR MINIMUM NETWORK AREA(km^2) PER STATION
I	Flat regions of temperate, mediterranean, and tropical zones	1,000 - 2,500
II	Mountainous regions of temperate mediterranean and tropical zones.	300 - 1,000
	Small mountainous islands with very irregular precipitations, very dense stream network	140 - 300
III	Arid and polar zones	5,000 - 20,000

To further reduce the chance of under representation, each zone should include a sufficient number of stations to cover the range of the physical and climatic characteristics which affect the streams in the zone. Without the benefit of a network, however, one must make some assumptions based on the experiences of others in an attempt to determine which parameters are the most significant.

Small drainage streams tend to be more discrete in that their range of characteristics within the watershed tend to be narrower in scope than the average of the zone, if based on their location. For example, a small stream in the upper reaches of a basin may have a greater than average slope and precipitation than a stream in a valley bottom. These small streams may therefore account for much of the variance in the hydrologic regime within a zone. Because of this fact, a larger proportion of stations with smaller watersheds are desirable, once the 'drainage range sampling' criteria has been addressed. In selecting small stream stations, there is some merit in monitoring a watershed within the drainage area of a station of a larger watershed. This placement will provide added information on flow routing and help to determine any significant variation in the rainfall/runoff relationship within the watershed.

Table 7.2

Minimun Network by Zone Using WMO Criteria

Zone	Region Type	Area (approx.) km^2	Suggested Number of Stations[1]	Present Number of Stations[2]	Change Required
1	I	5200	3	3	0
2	I	4500	3	3	0
3	II	4600	4	3	1
4	II	1800	2	1	1
5	II	7400	7	12	-5
6	II	3800	4	0(2)[3]	4
7	I	5200	3	3	0
8	I	7100	4	4	0
9	II	3200	3	2(1)	1
10	I	6600	5	2(2)	3
11	II	5300	4	1(2)	3
12	II	4400	4	2	2
13	I	3500	2	4	-2
14	II	4100	4	1(3)	-3
15	I	3300	2	5	-3
16	II	n/a	n/a	1(1)	n/a
TOTAL			54	47(6)[4]	2

Note: 1 Based on WMO Minimum Network Criteria
2 Including only natural flow stations suitable for Regional Hydrology
3 Numbers in brackets indicate number of stations which monitor watersheds which cross zone boundary.
4 The total number of stations is 53

By using the drainage range sampling criteria, it appears that a more representative network would be developed and in the New Brunswick case, the number of stations for a basic network would not be dramatically different from the WMO guideline although the distribution and range of station types would be better defined.

7.2 SELECTING REPRESENTATIVE STREAMS FOR A NATURAL FLOW NETWORK

The first step in the selection of representative streams for the natural flow network is to identify the main rivers in each of the zones. It is these streams that are the main building blocks of the water resources and the major summing points in the network. The sizes of the drainage areas of these "major" rivers obviously vary from one zone to the next, ranging from a little over a hundred to a few thousand square kilometres.

At the upper end of the scale of these major rivers are a few large rivers such as the Saint John River which complicate this zone concept. By passing across zones, they lump together the characteristics of the contributing zones. These larger rivers are in themselves most important to the water resources and consequently the economy of the region, but data from hydrometric stations on these rivers are limited in their application to the understanding of their own hydraulic/hydrologic characteristics. Their sizes or drainage areas are generally so much larger than any other streams of the region that they are less representative due to the lack of streams of similar size and consequently these large rivers are of little use to this data transfer process. Stations such as these should therefore not be included in the 'drainage range sampling' selection criteria but they should still be considered as additional parts of the minimum network.

Table 7.3 lists the major rivers in each zone accompanied by their WSC basin division identifier, whether the stream is presently gauged or has been monitored in the past and whether or not the stream is regulated. The larger rivers mentioned above are also indicated. It is interesting to note that of the 55 streams named (without double counting multi-station streams) only 9 have never been monitored. More importantly is the fact that none of the 15 zones is without a gauged major natural flow stream. This is a good foundation on which to build.

From the list of streams in Table 7.3, a representative sample of sites should be measured. From the natural hydrology point of view, streams which are regulated should

Table 7.3

Major Rivers of New Brunswick

Zone	Division	Measured	Stream Name	Comment
1	1AQ	A	Lepreau River	
		A	Magaguadavic River	minor regulation
	1AR *	A	St. Croix River	major regulation
		-	Digdeguash River	
2	1AM	A	Oromocto River	
	1AO *	L	Saint John River	major regulation
		-	Little River	
	1AP *	L	Saint John River	major regulation
		A	Nerepis River	
3	1AP *	L	Saint John River	major regulation
		A	Kennebecasis River	
	1BU	A	Petitcodiac River	
		-	Memramcook River	
4	1BV	D	Big Salmon River	
		A	Point Wolfe River	
5	1AJ *	A	Saint John River	major regulation
		A	Meduxnekeag River	international
		A	Big Presque Isle River	international
		A	Becaguimec River	
	1AK *	A	Saint John River	major regulation
		A	Shogomoc River	
		-	Keswick River	
		A	Nackawic River	
		-	Pokiok River	
		A	Eel River	
	1AL	A	Nashwaak River	
6	1BN	-	Cains River	
	*	-	S.W. Miramichi River	continued from 1BM
	1BO *	A	S.W. Miramichi River	continued from 1BN
		A	Renous River	
7	1AN	A	Salmon River	
	1AP	A	Canaan River	
8	1BO	A	Bartibog River	
	1BR	A	Kouchibouguac River	
	1BS	-	Richibucto River	
		-	Buctouche River	
	1BT	-	Tantramar River	

continued...

Table 7.3 (concluded)

Major Rivers of New Brunswick

Zone	Division	Measured	Stream Name	Comment
9	1AE	A	Fish River	in U.S.A
	1AF *	A	Saint John River	regulation
		-	Little River	
		-	Salmon River	
	1AG	A	Aroostook River	regulated U.S.A.
10	1AH	A	Tobique River	major regulation
	1BA	D	Restigouche River	part in zone 14
	1BC	A	Restigouche River	continued from 1BA
	1BE	A	Upsalquitch River	
11	1BM	-	S.W. Miramichi River	
	1BO	A	Renous River	
		-	Dungarvon River	
	1BP	A	Little S.W. Miramichi R.	
12	1BK	A	Nepisiquit River	regulated
	1BQ	A	N.W. Miramichi River	
		-	Big Sevogle River	
13	1BL	A	Big Tracadie River	
		-	Tabusintac River	
	1BO	A	Barnaby River	
14	1AD *	A	Saint John River	unregulated
		A	Madawaska River	regulated(QUE.)
	1AF *	A	Saint John River	regulation
		A	Green River	minor regulation
	1BA	D	Restigouche River	
		-	Gounamitz River	
	1BB	-	Kedgwick River	
	1BC	-	Patapedia River	interprovincial
15	1BJ	A	Jacquet River	
		A	Tetagouche	
	*	A	Restigouche	
16	-- *	USA	Saint John River	outside Canada

A - active measurement station in this zone
D - discontinued measurement station
L - water levels only
USA - located in U.S.A.
- - not previously measured
* - large river of region

---

only be measured above their regulation. Doing this effectively reduces most major rivers with regulation to secondary streams in terms of the network selection.

The next selection of streams should be those with medium and small drainage areas. A good distribution of drainage areas is imperative as drainage area is singularly the most important variable in any empirical relationship dealing with flow. Here again, size of the streams is relative to the range of stream sizes in the area. The selection of streams in these categories is obviously not as restictive, due to the greater abundance of streams as they get smaller. The importance then, is to be selective in establishing these stations so that a representative sample is monitored over the region.

As a strict minimum sample of stations for a zone, a total of three should be selected from large, medium and small streams. The size range is of course relative to the available streams on the zone. This will not give the full variation of the population but it will provide a baseline from which to build a more comprehensive network. By selectively monitoring additional small and medium sized streams, a better estimate of the sample variance will be realized. It is obvious that some zones are more complex than others in terms of their physiography and their range in stream size. Efforts should be spent to ensure that this complexity is addressed by increasing the number of stations in the sample size.

8.0 CONCLUSIONS AND PROPOSED MINIMUM NETWORK

Given a good knowledge of the spectrum of physiographic, climatic and land use characteristics associated with the streams of the Province of New Brunswick, it is possible to divide the area into zones which can be generally classed as homogeneous for regional hydrology purposes. This provides a solid framework from which the hydrology can be studied. In comparing these zones to the placement of stations in the present network, it appears that there is a good representation of the major rivers presently included; however, a lack of representation is noted in most zones for small to medium sized streams.

In the present state of development the existing land use database can be used in a qualitative way in an analysis such as this, but its full impact in a quantitative application will require more sophisticated analytical methodologies. With such a tool it would be reasonable to study the effect this data would have on an analysis of the natural hydrology at the zone scale.

This report points out some shortcomings and possible redundancies in the present natural hydrology network when considering a minimum representative network. An example of a balanced network based on a **minimum** of 3 stations per zone is given in Table 8.1. In some cases the reactivation of a discontinued station has been proposed for consideration to meet this need and in other instances the stream size only has been indicated to allow for input from user identified needs. Zones 1, 3, 5, 6, 9, 10 and 11 require one or two additional stations based on the range of the drainage areas of streams within the zone. Zones 5, 13 and 15 require less stations than are provided in the present network to achieve **a minimum coverage** of the natural hydrology.

Additional stations can be added to increase the representation in areas where there is more activity affecting the water resouces and consequently a demonstrated need for greater accuracy in transferring flow data. However, it was not, the purpose of this background report to propose the final hydrometric network design, since other factors such as operational and user needs must be addressed. These aspects of the total study are dealt with in the companion report: "Background Report No. 3 - Regional Hydrology and Data Transfer Methodologies" and the "Principal Report - New Brunswick Hydrometric Network Evaluation".

Table 8.1

MINIMUM REGIONAL HYDROLOGY NETWORK SCENARIO

	STATION/STREAM	DRAINAGE AREA
ZONE 1:	01AQ001	239 km^2
	01AR006	115 km^2
	restart 01AR008	43.0 km^2
	new station	>500 km^2
ZONE 2:	01AM001	557 km^2
	01AP006	293 km^2
	new station	<100 km^2
ZONE 3:	01AP004	1100 km^2
	01BU002	391 km^2
	01BU003	129 km^2
	new station	<100 km^2
ZONE 4:	01BV006	130 km^2
	restart 01BV008	287 km^2
	restart 01BV005	29.5 km^2
ZONE 5:	01AJ003	1210 km^2
	01AK001	234 km^2
	01AK008	531 km^2
	01AL002	1450 km^2
	01AL003	6.48 km^2
ZONE 6:	* 01BO001	5050 km^2
	* 01BO002	611 km^2
	new station	>500 km^2
	new station	100-500 km^2
	new station	<100 km^2
ZONE 7:	01AN001	34.4 km^2
	01AN002	1050 km^2
	01AP002	668 km^2
ZONE 8:	01BO003	484 km^2
	01BS001	166 km^2
	01BT001	32.1 km^2

continued...

Table 8.1 (concluded)

MINIMUM REGIONAL HYDROLOGY NETWORK SCENARIO

	STATION/STREAM	DRAINAGE AREA
ZONE 9:	* 01AE001	2260 km^2
	01AF007	339 km^2
	01AG002	199 km^2
	new station	<100 km^2
ZONE 10:	* 01BC001	3160 km^2
	* 01BJ007	7740 km^2
	01AH005	230 km^2
	01BE001	2270 km^2
	new station	500-1000 km^2
	new station	<100 km^2
ZONE 11:	* 01BO001	5050 km^2
	* 01BO002	611 km^2
	01BP001	1340 km^2
	new station	<100 km^2
ZONE 12:	01BK006	13.0 km^2
	01BQ001	948 km^2
	new station	100-500 km^2
ZONE 13:	01BL002	173 km^2
	01BL003	383 km^2
	new station	<100 km^2
ZONE 14:	* 01AD002	14700 km^2
	* 01BC001	3160 km^2
	* 01BJ007	7740 km^2
	new station	400-1000 km^2
	new station	<200 km^2
ZONE 15:	01BJ003	510 km^2
	01BJ010	190 km^2
	01BJ012	43.2 km^2
ZONE 16:	* 01AE001	2260 km^2

* - Some stations may appear in more than one zone

9.0 RECOMMENDATIONS

As a first priority to developing a network which will meet the basic requirements of the regional hydrology, it is recommended that a minimum network be established based on a minimum of 3 stations per physiographic-climatic zone.

Using other criteria, such as the range of influencing parameters and the range in size of streams in a zone, the minimum should be increased above three stations per zone to maintain the balance of the network representation. A proposed minimum natural hydrology network scenario is presented in Table 8.1. It is recommended that in carrying out the final design of the entire network in the companion reports of this evaluation that the minimum network, as proposed in this report to be considered a minimum and not an optimum.

The present network has sampled a good portion of the major streams of the province; however, the network is deficient in its sampling of smaller streams. Steps must be taken to rectify this deficiency. Since smaller streams will be narrower in their range of physiographic, climatic and land use characteristics in comparison to the larger streams, a larger proportion of the smaller streams is required to sample the wider variation.

A database should be developed which would make it easier to determine some of the discrete but significant physiographic, climatic and land use factors as well as hydrologic parameters for specific watersheds without having to start from first principles. This could be in the form of additions to the square grid analysis database, modifications to the present land use databases, development of large scale basin maps or some hybrid of all of these.

REFERENCES

Canadian National Committee, Hydrological Mapping. Proceedings of Workshop seminar, Secretariat of Canadian National Committee, The International Hydrological Decade, Ottawa, 1969.

Bostock, H.S., Physiographic Regions of Canada. Geological Survey of Canada, Map 1254A, Ottawa, 1970.

New Brunswick Department of the Environment, Water Resources Branch, Bathurst Planning Region Water Resources Review, 1979.

New Brunswick Department of the Environment, Water Resources Branch, Campbellton-Dalhousie Planning Region Water Resources Review, 1979.

New Brunswick Department of the Environment, Water Resources Branch, Edmundston Planning Region Water Resources Review, 1981.

New Brunswick Department of the Environment, Water Resources Branch, Fredericton Planning Region Water Resources Review, 1980.

New Brunswick Department of the Environment, Water Resources Branch, Moncton Planning Region Water Resources Review, 1984.

New Brunswick Department of the Environment, Water Resources Branch, Newcastle-Chatham Planning Region Water Resources Review, 1984.

New Brunswick Department of the Environment, Water Resources Branch, Saint John Planning Region Water Resources Review, 1977.

Rampton, V.N., Gauthier, R.C., Thibault, J., and Seaman, A.A., Quaternary Geology of New Brunswick. Memoir 416, Geological Survey of Canada, Ottawa, 1984.

Rowe, J.S., Forest Regions of Canada. Publication No. 1300, Canadian Forestry Service, Department of the Environment, Ottawa, 1972.

World Meteorlogical Organization, Guide to Hydrological Practices. WMO - No. 168, Secretariat of the World Meteorological Organization, Geneva, Switzerland, 1974.

LIST OF CONTRIBUTORS

This report was written by Wm. A. Brimley, of the Hydrology Division, Water Resources Branch, Environment Canada, Dartmouth, Nova Scotia.

The delineation and description of the Climatic Regions was provided by John Dublin of Scientific Services, Atmospheric Environment Service, Environment Canada, Fredericton, New Brunswick.

The information on land use was provided by J. Arbour, Inland Waters/Lands, Environment Canada, Dartmouth, N.S.

The report was reviewed by:

D.C. Ambler, Water Resources Branch, Environment Canada, Dartmouth, N.S.

B.C. Burrell, Water Resources Planning Branch, New Brunswick Department of Municipal Affairs and Environment, Fredericton, N.B.

Z. Davar and D. Gingras, Water Planning and Management Branch, Environment Canada, Dartmouth, N.S.

A. R. Perks, Water Resources Branch, Environment Canada, Hull, Que.